



ACCURACY OF WORLDVIEW PRODUCTS



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Introduction

DigitalGlobe owns and operates a world-class constellation of high resolution, high accuracy Earth imaging satellites. Accuracy testing is performed on a regular basis by comparing images to highly accurate ground control points. This paper discusses the process that is used to assess accuracy and the resulting accuracy statements for WorldView-1 and WorldView-2 satellite products.

DigitalGlobe offers a range of imagery products with a variety of processing, radiometric correction, and geometric enhancement options which result in differing levels of accuracy. The product levels are summarized in Table 1: WorldView Product Summary.

Core Products	Accuracy Specifications			Processing			Geographic Availability
	CE90/LE90	RMSE	NMAS Scale	Radiometrically & sensor corrected	Georectified	Orthorectified	
System-Ready (Basic)	5 m*	2.3 m*	N/A	X			Worldwide
System-Ready (Basic stereo pair)	5 m*/5 m	2.3 m	N/A	X			Worldwide
View-Ready (Standard)	5 m*	2.3 m*	N/A	X	X		Worldwide
View-Ready (Ortho Ready Standard)	5 m*	2.3 m*	N/A	X	X		Worldwide
View-Ready (Ortho Ready Stereo)	5 m*/5 m	3.3 m	N/A	X	X		Worldwide
Map-Ready (Map Scale Ortho)	4.2 m	2.0 m	1:5,000	X		X	Worldwide, limited to fine DEM coverage (SRTM + USGS NED)
Map-Ready (Map Scale Ortho)	10.2 m	4.8 m	1:12,000	X		X	Worldwide, limited to fine DEM coverage (SRTM + USGS NED)
Map-Ready (Map Scale Ortho)	25.4 m	11.8 m	1:50,000	X		X	Worldwide, limited to fine DEM coverage (SRTM + USGS NED)

Table 1: WorldView product summary

*Less than 30 degrees off NADIR and excluding terrain effects

*The representative of a point accuracy statement and not of a map accuracy statement

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Measuring Geolocation Accuracy

Absolute geolocation accuracy is a measure of the location of an object, as it appears in a product, with respect to its true location on the Earth. Geolocation accuracy is driven by the sensors and models used in the imagery collection system and by terrain displacement when the image pixels are projected to a surface on the Earth.

Geolocation accuracy is determined by comparing a known, surveyed location (typically a ground control point), to the corresponding photo-identifiable feature in an image product. For an individual control point, the geolocation error is measured by calculating the difference between the observed location in the product and the known, surveyed location.

DigitalGlobe specifies geolocation accuracy using the CE90 and LE90 standards. CE90 is the circular error at the 90th percentile. This means that a minimum of 90 percent of the points measured has a horizontal error less than the stated CE90 value. LE90 is the 90th percentile linear error, meaning that a minimum of 90 percent of vertical errors fall within the stated LE90 value.

The geolocation accuracy of WorldView orthorectified products is specified in Table 1: WorldView Product Summary. The specified pointing and map accuracy statement is valid for all WorldView images collected with a satellite off-nadir angle of less than 30 degrees. Accuracy for Basic and Standard products excludes terrain-induced offsets due to projection to a coarse digital elevation model or datum, which is a constant surface used to represent the Earth.

Horizontal Accuracy of WorldView Basic and Standard Products

Basic, Standard and Ortho Ready Standard products are not corrected for terrain-induced offsets. In order to determine the location of a feature in the image, the feature must be projected to known height.

To determine horizontal accuracy, a ground control point (GCP) with known horizontal and vertical locations is identified in the image. The pixel representing that GCP is projected to the vertical height of the GCP, and the resulting location of the pixel is calculated. The error between the location of the projected pixel and the GCP is the error for that point.

Figure 1 shows a known GCP that has been measured on the ground, and the GCPs actual geodetic location. The pixel representing that point in the image is projected from the satellite to the known height of the GCP, and the apparent geodetic location of the pixel is calculated. The difference between the actual geodetic location and the apparent geodetic location is the error for that pixel.

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When measuring the geolocation accuracy of a satellite imaging system, a large number of images are used to determine the CE90 with sufficient confidence. The CE90 for a set of images is the value that, if represented as a radius of a circle, would be greater than 90% of all measured image error values.

Basic and Standard product accuracy represents the pointing accuracy of the satellite. This pointing accuracy is a different measure of accuracy than map accuracy. For this reason, the reported CE90 values for Basic and Standard products don't have the same predictable accuracy as the orthorectified products.

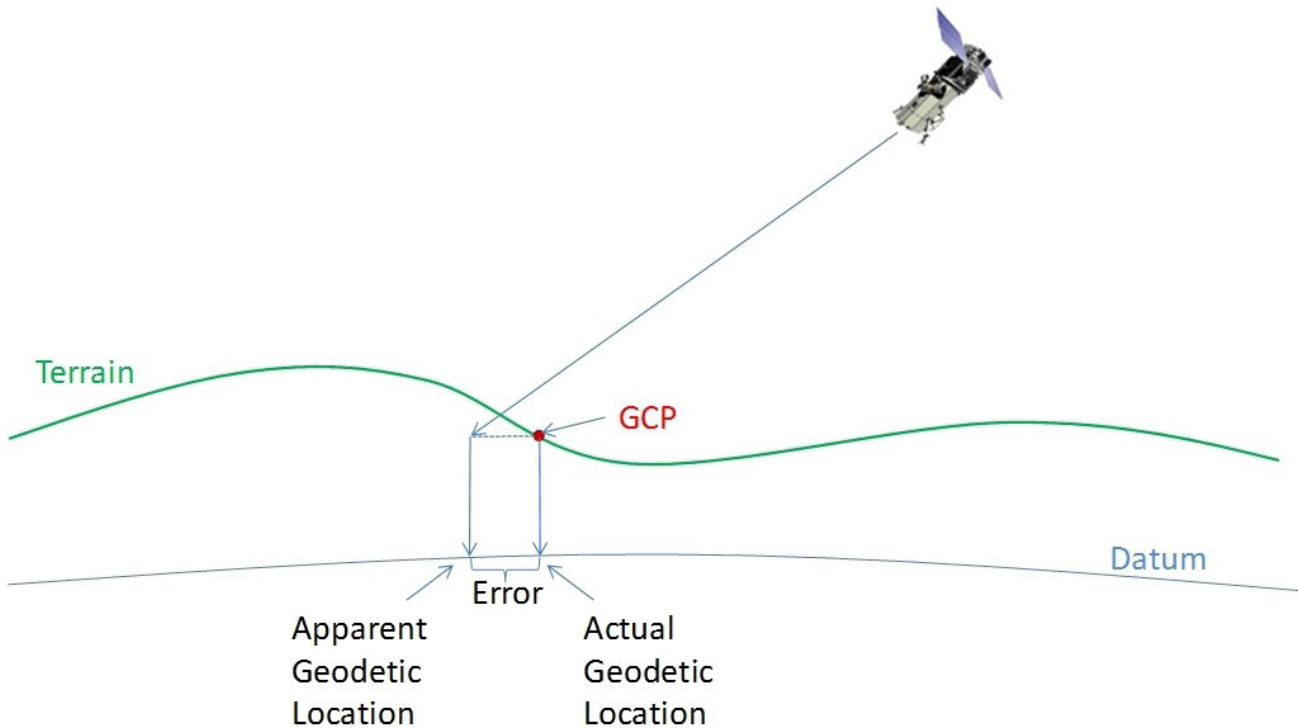


Figure 1: Accuracy with no terrain correction

The WorldView-1 horizontal accuracy is provided in Figure 2. In this scatter plot, the average two-dimensional geolocation accuracy for each of the 979 measured images is shown by a marker. The horizontal and vertical axes are error in the East and North directions, respectively, both in units of meters. The calculated CE90 accuracy of the entire group of images was 4.0 meters, and is signified by the black circle located on the plot.

The WorldView-1 horizontal accuracy versus time is provided in Figure 3. The images measured spanned a time period of twelve months, from October 1, 2010, to September 30, 2011. The calculated CE90 accuracy for each quarter over the test period is shown to exhibit the accuracy stability over time. WorldView-1 accuracy performance is better than the 5 meter accuracy specification, which is represented by the black line on the plot.

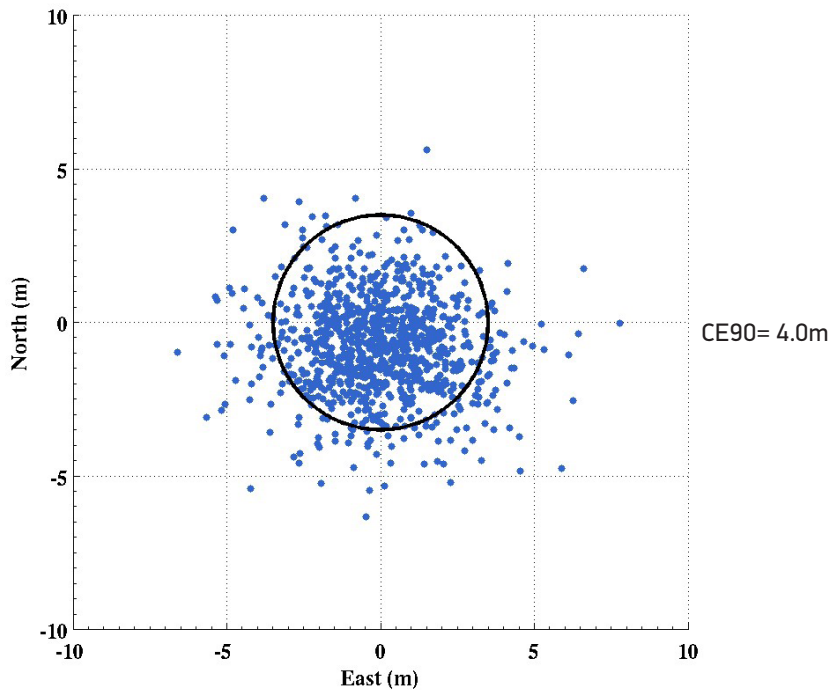


Figure 2: Horizontal accuracy of WorldView-1 Basic and Standard products

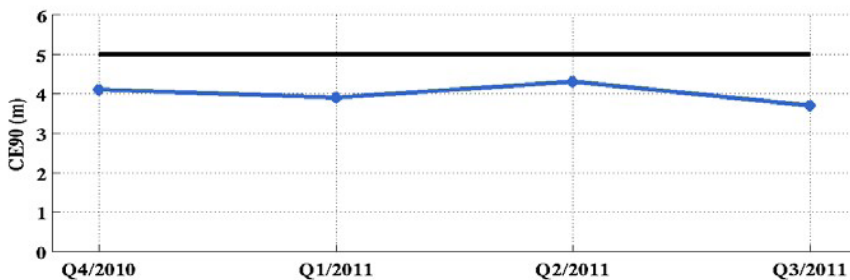


Figure 3: WorldView-1 CE90

The WorldView-2 horizontal accuracy is provided in Figure 4. In this scatter plot, the average two-dimensional geolocation accuracy for each of the 4,412 measured images is shown by a marker. The horizontal and vertical axes are error in the East and North directions, respectively, both in units of meters. The calculated CE90 accuracy of the entire group of images was 3.5 meters, and is signified by the black circle located on the plot.

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The WorldView-2 horizontal accuracy from October 1, 2010 to September 30, 2011, is provided in Figure 4. The calculated CE90 accuracy for each quarter over the test period illustrates consistent accuracy over time. WorldView-2 accuracy performance is better than the 5 meter accuracy specification, which is represented by the black line on the plot.

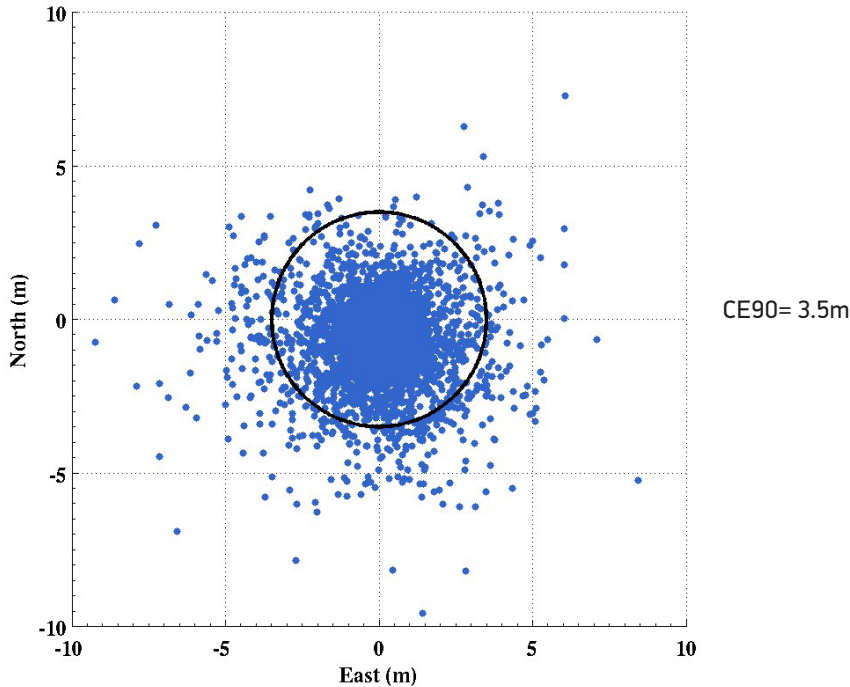


Figure 4: Horizontal accuracy of WorldView-2 basic and standard products

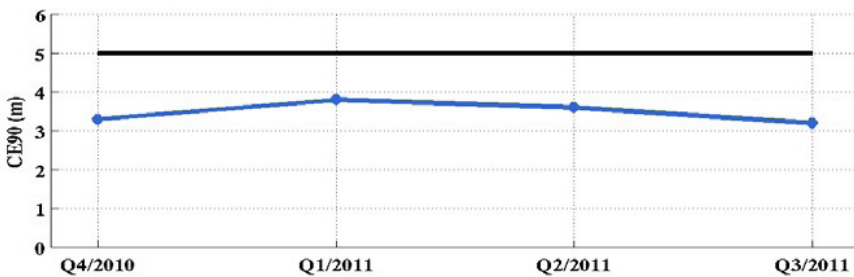


Figure 5: WorldView-2 CE90

Vertical Accuracy of WorldView Basic and Standard Products

Vertical accuracy is measured using the Basic Stereo product. For vertical accuracy, the pixel locations corresponding to a ground control point for each image of a stereo pair are combined to determine the estimated height. A vertical error relative to the known height is then measured. For a set of control points in the stereo pair, the LE90 accuracy is then calculated. Side by side experiments have shown that vertical accuracy achieved by Basic and Ortho Ready Standard products agree to within a fraction of a pixel.

Like horizontal accuracy, when dealing with vertical accuracy of a satellite imaging system, a large number of images are used to determine LE90 with sufficient confidence. However, due to the labor-intensive nature of working with stereo products, the number of test images to determine LE90 is lower than that used for CE90. The average vertical accuracy for each image is calculated and the LE90 of the group of images is the 90th percentile of the sorted vertical accuracies. The system LE90 will include 90 percent of all images measured.

WorldView-1 and WorldView-2 vertical accuracy results are provided in Figures 6 and 7, respectively. The results are shown by quarter over the test period of October 1, 2010, through September 30, 2011. The WorldView-1 LE90 for the entire period was 3.7 meters, using 181 Basic Stereo products. The WorldView-2 LE90 for the entire period was 3.6 meters, using 160 Basic Stereo products. WorldView-1 and 2 vertical accuracy performance meets the 5 meter accuracy specification, which is represented by the black line on the plots.

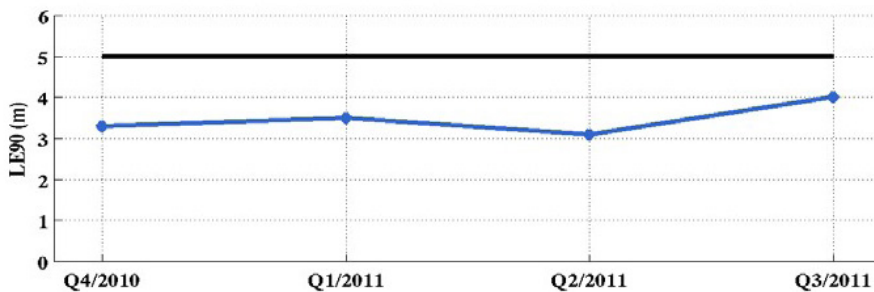


Figure 6: Vertical LE90 accuracy of WorldView-1 basic and standard products

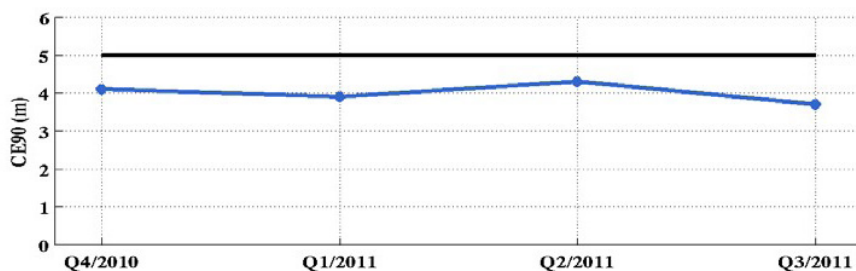


Figure 7: Vertical LE90 accuracy of WorldView-2 basic and standard products

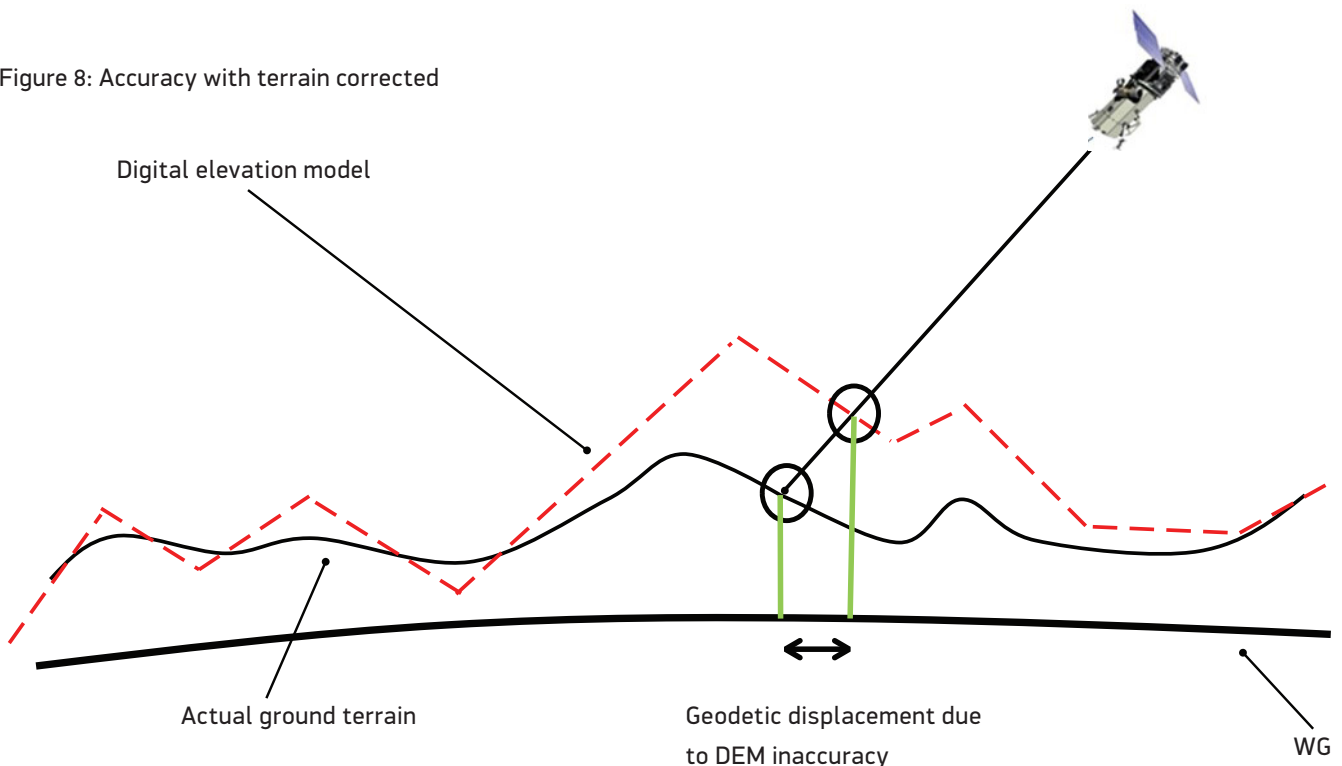
Accuracy of WorldView Orthorectified Products

Geolocation accuracy of ortho products is determined by creating ortho products over sites that contain a dense network of surveyed ground control points. The ground control points are used for accuracy testing purposes and are not used to correct the position of the image. The difference in the location of feature representing the control point in the image, and actual location of the control point is measured in the image. This difference is the error for that pixel. The errors for all the control points in the image are measured and these errors are used to calculate the accuracy of the image.

Figure 8 shows how errors in the elevation model will result in errors in the positional accuracy of the orthorectified product. When an image is orthorectified, the pixels are projected from the satellite to the elevation model, and projected down to the mapping datum. As seen in figure 8, differences between the elevation model and the terrain will result in errors of the location of features in the image. With orthorectified products, the image is corrected to a map projection, and each pixel has a map coordinate. Therefore the error of the control points can be measured directly in the image.

Basic and Standard products have error values that are lower than orthorectified products because the accuracy values do not include the removal of image distortion that are typically resolved with a precision digital elevation model (DEM). However, orthorectified products are more accurate and more representative of a true location on the Earth's surface.

Figure 8: Accuracy with terrain corrected



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Accuracy of WorldView Orthorectified Products

A study of 83 WorldView-1 and 97 WorldView-2 ortho products was conducted to determine the overall accuracy of WorldView ortho products. Accuracy was determined by measuring the difference in the coordinates of the surveyed feature and the coordinates of that corresponding feature in the ortho product. The CE90 was calculated for the set of measured ground control points in each image. Finally, the system CE90 was determined for each group of WorldView-1 and WorldView-2 images.

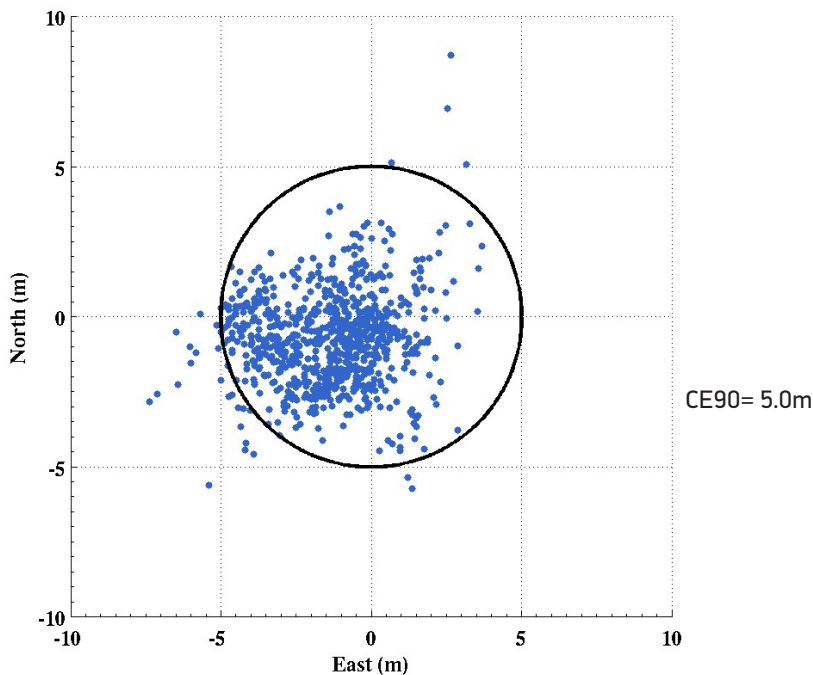


Figure 9: Accuracy of WorldView-1 orthorectified products

The accuracy of WorldView-1 ortho products is provided in Figure 9. There was a total of 818 point residuals measured from the 83 image products. Due to variations in collection geometry and therefore terrain error over the image strip, the error value for each point in every image is shown by a marker in this scatter plot. For ortho products, this provides a more complete representation of the error bias for each image strip. The horizontal and vertical axes are error in the East and North directions, respectively, both in units of meters. The calculated CE90 accuracy of the entire group of images was 5.0 meters, and is represented by the black circle located on the plot.

Accuracy of WorldView Orthorectified Products

A study of 83 WorldView-1 and 97 WorldView-2 ortho products was conducted to determine the overall accuracy of WorldView ortho products. Accuracy was determined by measuring the difference in the coordinates of the surveyed feature and the coordinates of that corresponding feature in the ortho product. The CEgo was calculated for the set of measured ground control points in each image. Finally, the system CEgo was determined for each group of WorldView-1 and WorldView-2 images.

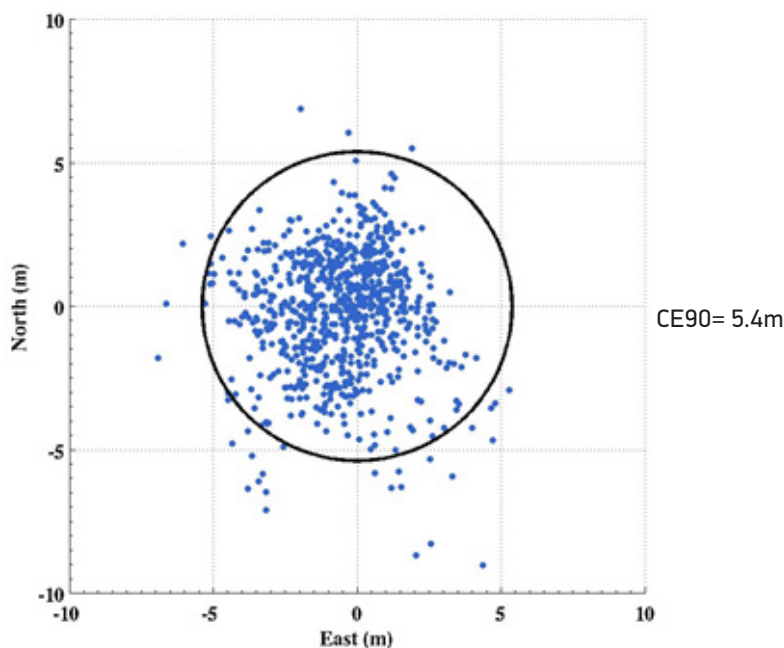


Figure 10: Accuracy of WorldView-2 orthorectified products

The accuracy of WorldView-2 ortho products is provided in Figure 10. There was a total of 790 point residuals measured from the 97 image products. The error value for each point in each sample image is shown by a marker in the scatter plot. The horizontal and vertical axes are error in the East and North directions, respectively, both in units of meters. The calculated CE90 accuracy of the entire group of images was 5.4 meters, and is represented by the black circle located on the plot.

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Summary

DigitalGlobe offers a range of WorldView imagery products, from Basic and Standard to Orthorectified. The horizontal accuracy specification for WorldView Basic and Standard products have a pointing accuracy of a 5 meters CE90, meaning that 90 percent of all WorldView Basic and Standard products will achieve a horizontal accuracy of 5 meters or better. The vertical accuracy for Basic and Ortho Ready Standard Stereo products is 5 meters LE90, meaning that 90 percent of all WorldView Basic and Standard products will achieve a vertical accuracy of 5 meters or better.

Horizontal accuracy was measured for 979 WorldView-1 images and 4,412 WorldView-2 Basic and Standard images. The resulting horizontal accuracy for WorldView-1 was 4.0 meters CE90, and WorldView-2 demonstrated an accuracy of 3.5 meters CE90. Vertical accuracy was measured for 181 WorldView-1 and 160 WorldView-2 Basic products, resulting in vertical accuracy for WorldView-1 of 3.7 meters LE90 and vertical accuracy of 3.6 meters LE90 for WorldView-2. There is a significant margin between demonstrated horizontal and vertical accuracies and their respective 5 meter CE90 and LE90 product specifications to account for extreme terrain.

The accuracy was measured for 83 WorldView-1 and 97 WorldView-2 ortho products and resulted in a demonstrated accuracy of 5.0 meters CE90 for WorldView-1, and 5.4 meters CE90 for WorldView-2.

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